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## FLAVOR OF POTATOES AS INFLUENCED BY ORGANIC INSECTICIDES*

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(Accepted for publication, March 15, 1950)

The problem of insect control in potato fields, especially with respect to wireworms, has long been of major importance. For many years the only wireworm controls available were either certain cultural practices or soil fumigation, both of which were costly and often impractical. During and immediately after World War II, a number of synthetic organic materials appeared that gave promise of being extremely effective against wireworms. A number of investigators have shown that when such materials as BHC, lindane, parathion or chlordan are introduced into the soil, excellent control of this pest was obtained.

BHC and lindane were found to be particularly effective at concentrations

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* Journal Series Paper, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology.

as low as 0.5 lb. of gamma isomer per acre. With the other materials concentrations ranging from 8-20 lbs. per acre are necessary for equal control.

Unfortunately, however, many growers, various marketing agencies and consumers have found that tubers grown in soils treated with these materials may on occasions have distinct off-flavors.

Pepper, *et al* (1949) presented taste-test data on tubers grown in soils treated with various insecticides and showed that certain treatments produced definite off-flavors. There was also evidence that the off-flavors were greatly reduced when the soils had been treated a year previous to the planting of the potato crop.

The purpose of this paper is to present taste test data on tubers grown in fields that had been treated for wireworm control and on others where the plants had been either dusted or sprayed for control of foliage insects.

## Procedures and Materials Used:

*A. Soil Treatments.*—In the spring of 1948 a plot of sod land that had never been treated with insecticides was obtained for experimental work. The field was plowed, divided into plots 35 feet by 25 feet so that there were three randomized plots for each treatment plus a number of untreated checks. The materials were applied with a hand-operated fertilizer distributor and great care was exercised to prevent drifting of the materials from one plot to another. Immediately after application the field was harrowed. The various insecticides used were so diluted with talc or pyrophyllite that at an application rate of 200 pounds per acre the desired amount of toxicant was applied.

A few days after treatment the field was planted to potatoes (Katahdin). Throughout the growing season the usual cultural procedures were used. None of the synthetic insecticides and no fungicides were used, however, there being but three applications of a spray containing 0.01 per cent rotenone applied for insect control.

The following list gives the materials used in the soil treatments

| | | | |
|---|---|---|---|
| 1. | Technical BHC | 0.5 | lb. g.i./acre |
| 2. | Refined (deodorized) BHC | 0.125 | " " |
| 3. | " | 0.25 | " " |
| 4. | " | 0.50 | " " |
| 5. | " | 1.00 | " " |
| 6. | Lindane | 0.25 | " " |
| 7. | " | 0.50 | " " |
| 8. | " | 1.00 | " " |
| 9. | Parathion | 5 | lbs./acre |
| 10. | " | 10 | " |
| 11. | " | 20 | " |
| 12. | Chlordan | 2 | " |
| 13. | " | 4 | " |
| 14. | " | 8 | " |
| 15. | " | 16 | " |
| | Check (no treatment) | | |

In the fall of 1948, samples of tubers from the various treatments were tested for quality.

This same field was again planted to potatoes (Katahdin) in the spring of 1949 with no additional applications of insecticides being made to the soil, and as before none of the synthetic materials or fungicides was used. Six applications of a 1 per cent rotenone dust were used for insect control.

*B. Spray and Dust Treatments—1949.*—A series of experimental plots in another area was planted to Katahdins and were sprayed or dusted with the following materials.

*Dusts*

1. 3 per cent DDT (no fungicide)
2. 3 per cent DDT plus 7 per cent tribasic copper sulfate.
3. 1½ per cent DDT impregnated plus 7 per cent tribasic copper sulfate.
4. 1 per cent parathion plus 7 per cent tribasic copper sulfate.

*Sprays*

5. 50 per cent DDT 2 pounds/100 gallons (no fungicide).
6. 50 per cent DDT 2 pounds/100 gallons plus 4 pounds tribasic copper sulfate.
7. 25 per cent DDT emulsion 1 quart/100 gallons plus 4 pounds tribasic copper sulfate.
8. 25 per cent parathion plus 4 pounds tribasic copper sulfate.

Nine applications of these materials were made at 10-day intervals during the season. Power equipment was used for all treatments using approximately 100 gallons per acre per treatment in the case of the sprays and 35-40 pounds per acre per treatment with the dusts.

Soon after harvest samples of tubers from all treatments were taken to the Food Technology laboratory for quality analysis.

## Preparation of Potatoes for Taste Testing:

The potatoes were kept in storage at room temperature and humidity until ready for cooking. On the day assigned for testing, four tubers of uniform size from each lot were washed in warm water and cooked in pressure cookers to which one-half cup of water had been added. The smaller tubers were cooked for 10 minutes and the larger ones for 15 minutes under 15 pounds pressure. At the end of the cooking period the pressure was immediately lowered by immersing the pans in cold water.

The potatoes were then peeled and placed on plates without addition of such condiments as butter or salt. Seven treated samples and one check were tasted at each period, there being but one tasting period per day. All the samples were numerically coded to prevent identification. The tasters were allowed to sample at random, and the quantity tasted was determined by the individual.

## RESULTS:

A. Taste test data on tubers from soil treatments.

TABLE 1—*BHC taste tests for 1948-1949.*

| Treatment | Per cent Satisfactory | | No. Tests for Quality | |
|---|---|---|---|---|
| | 1948 | 1949 | 1948 | 1949 |
| Check | 89 | 77 | 120 | 116 |
| 1* | 24 | 58 | 13 | 24 |
| 2 | 76 | 58 | 42 | 38 |
| 3 | 70 | 61 | 37 | 36 |
| 4 | 67 | 70 | 46 | 37 |
| 5 | 42 | 59 | 12 | 33 |

* See corresponding numbers in list of materials.

TABLE 2—*Lindane taste tests for 1948-1949.*

| Treatment | Per cent Satisfactory | | No. Tests for Quality | |
|---|---|---|---|---|
| | 1948 | 1949 | 1948 | 1949 |
| Check | 89 | 77 | 120 | 116 |
| 6* | 64 | 77 | 12 | 44 |
| 7 | 73 | 77 | 11 | 43 |
| 8 | 57 | 61 | 7 | 43 |

* See corresponding numbers under list of materials.

TABLE 3—*Parathion taste tests for 1948-1949.*

| Treatment | Per cent Satisfactory | | No. Tests for Quality | |
|---|---|---|---|---|
| | 1948 | 1949 | 1948 | 1949 |
| Check | 89 | 77 | 120 | 116 |
| 9* | 82 | 69 | 11 | 35 |
| 10 | 92 | 68 | 11 | 38 |
| 11 | 82 | 50 | 11 | 36 |

* See corresponding numbers in list of materials.

TABLE 4—*Chlordan taste tests for 1948-1949.*

| Treatment | Per cent Satisfactory | | No. Tests for Quality | |
|---|---|---|---|---|
| | 1948 | 1949 | 1948 | 1949 |
| Check | 89 | 77 | 120 | 116 |
| 12 | 55 | 68 | 11 | 39 |
| 13 | 68 | 76 | 38 | 42 |
| 14 | 88 | 72 | 37 | 46 |
| 15 | 70 | 72 | 40 | 36 |

* See corresponding numbers in list of materials.

B. Taste test data on tubers from dust and spray treatments.

TABLE 5—*Taste tests data on tubers from dust plots for 1949.*

| Treatment | Per cent Satisfactory | No. Tests for Quality |
|---|---|---|
| 1* | 82 | 11 |
| 2 | 83 | 23 |
| 3 | 67 | 12 |
| 4 | 15 | 13 |

* See corresponding numbers in list of materials.

TABLE 6—*Taste test data on tubers from spray plots for 1949.*

| Treatment | Per cent Satisfactory | No. Tests for Quality |
|---|---|---|
| 5* | 56 | 33 |
| 6 | 60 | 15 |
| 7 | 54 | 11 |
| 8 | 33 | 9 |

* See corresponding numbers in list of materials.

## GENERAL DISCUSSION AND SUMMARY

The results obtained from taste tests are always subject to question since the tasting technique is more subjective than objective. It is, however, the only method for determining taste acceptability.

The data presented are based on averages of a series of taste tests conducted by a number of individuals, most of them having had previous experience in this type of testing. The testing periods were so arranged that no more than 7-8 samples were judged at any one time, thus reducing the incidence of taste satiation. The handling of the samples, the cooking techniques and the taste testing procedures for all the tests were kept as uniform as possible.

Just as taste tests are subject to question due to individual preferences and reactions, undoubtedly it is also true that such environmental factors as precipitation and temperature and the distribution of these factors during the growing season will have an influence on the physiology of the developing tubers with a resulting influence on their quality. It is quite probable that the weather conditions existing in New Jersey during the 1949 season had a definite effect on potato quality.

The state experienced one of the hottest and driest summers on record. The precipitation from the first of May to the first of October was 16.58 inches. Its distribution, however, occurred in the following manner:

| Date | No. Days | Precipitation in Inches |
|---|---|---|
| May 1-May 26 | 27 | 4.62 |
| May 27-July 12 | 46 | 0.41 |
| July 13-July 18 | 6 | 3.59 |
| July 19-Aug. 11 | 25 | 0.48 |
| Aug. 12-Aug. 31 | 19 | 2.53 |
| Sept. 1-Sept. 30 | 30 | 4.95 |
| | Total | 16.58 |

During the periods of drought (June, July, August) there were 34 days when the temperatures were over 90°F., and 50 days over 85°F.

The results of the taste tests conducted on tubers grown in soils treated with various insecticides show that technical BHC, when applied just prior to planting, imparts decided off-flavors, but that these effects are markedly reduced in the following year's crop. (See graph 1, treatment 1.)

Off-flavors imparted by the refined BHC and lindane are not so pronounced and the second year's effect of lindane is not so noticeable as that of the refined material. (See graphs 1 and 2.)

In the parathion tests the second year's taste results indicate more off-flavor than was apparent the first year. (See graph 3.) No logical explanation for this phenomenon can be given. Chemical analysis of the soils from the parathion treatments showed little or none present shortly after the harvest of the first year's crop. Conceivably there might have been degradation products of parathion present that would not show in the chemical tests but which could have affected tuber quality. Growth factors, as influenced by possible parathion residues or abnormal growing conditions, might also be to blame.

In the chlordan tests, it is interesting to note the trend of the satisfactory figures from the two pound to the eight pound treatments in 1948. (See graph 4.) This inverse effect is absent in the 1949 tests and all the treatments were essentially as acceptable as the checks.

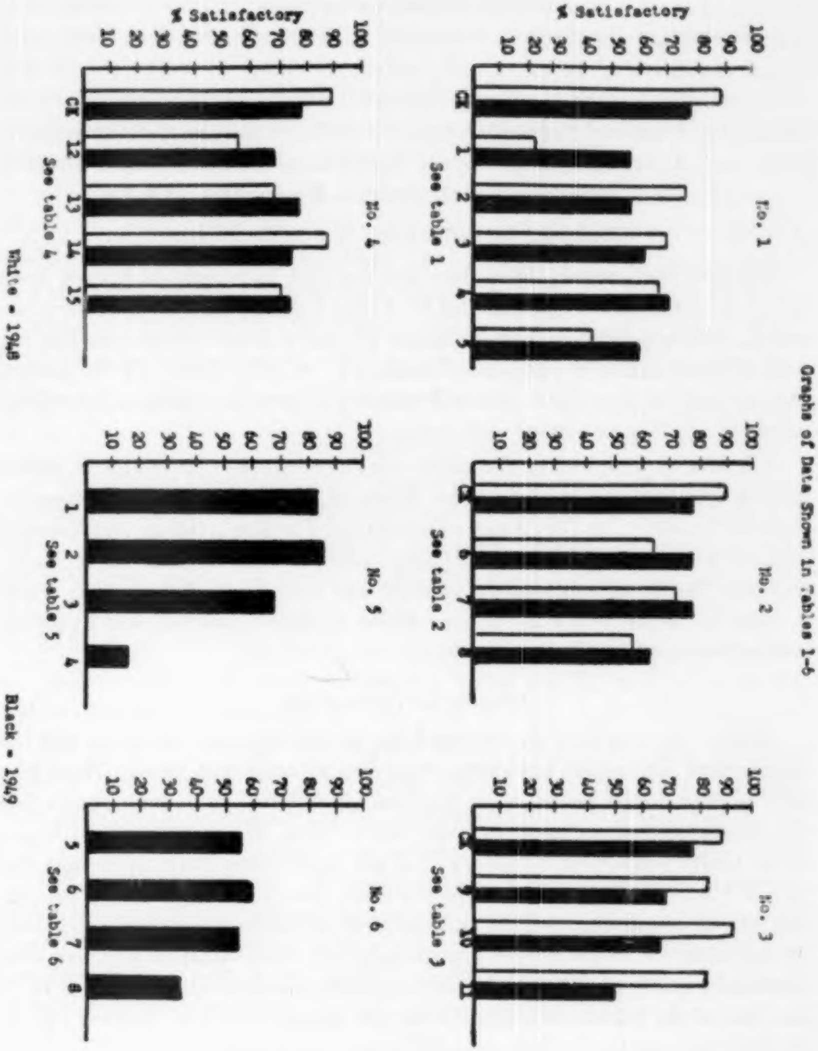
In the dust and spray treatments, the taste tests show that the dust plot tubers rated somewhat higher than those from the sprays, with the exception of parathion. In both cases the tubers from the parathion treatments were decidedly off-flavor.

Since the results of these tests are for one season only and since the season itself was so abnormal with respect to growing conditions, no definite statement as to the effects of the various insecticide formulations on tuber quality can be made.

Although soil applications of certain materials rather definitely have an effect on tuber quality, as shown by the 1948-1949 data, the rather drastic off-flavors found in the tubers from the dust and spray treatments, especially in the case of parathion, suggest that other factors, such as environmental conditions, may also play an important role in affecting potato tuber quality.

## Literature Cited

1949. Pepper, B. B., J. P. Reed and J. C. Campbell. Investigations on wireworm control with organic insecticides in New Jersey. Amer. Potato Jour. 26(9): 315-325.


Graphs of Data Shown in Tables 1-6
% Satisfactory
No. 1
See table 1
No. 2
See table 2
No. 3
See table 3
No. 4
See table 4
No. 5
See table 5
No. 6
See table 6
White - 1948
Black - 1949

# SEPARATION OF HOLLOW HEART POTATO TUBERS BY MEANS OF SIZE GRADING, SPECIFIC GRAVITY, AND X-RAY EXAMINATION[1]

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Potatoes that contain more than five per cent by weight of hollow heart tubers do not meet the standard for U. S. No. 1 potatoes (10). In some years and in certain areas the high incidence of hollow heart in varieties like the Irish Cobbler makes it difficult to obtain a U. S. No. 1 pack. At the present time no method is available that will enable a grower to separate hollow heart tubers except that of cutting each tuber.

The studies reported in this paper were conducted to determine if hollow heart tubers could be graded out by means of (1) size grading, (2) flotation (specific gravity), or (3) X-ray examination. The size grading and flotation methods were carried out with potatoes collected from the Red River Valley in 1948. The X-ray examination method was carried out at University Farm in 1944, incidental to a study of the relation of variety, spacing, and irrigation to the development of hollow heart.

## REVIEW OF LITERATURE

Krantz (3) has recently reviewed the literature on hollow heart and has summarized our present knowledge regarding its cause and nature. Those who have worked on the hollow heart problem (1, 4, 5, 6, 7, 8, 9) have shown that this defect is most prevalent in large tubers. Thus, Werner (8) found in one lot of tubers containing a total of 15.8 per cent hollow heart by weight that only 0.9 per cent occurred in tubers smaller than 225 grams (8.75 ounces) whereas the remaining 14.9 per cent occurred in tubers larger than 225 grams. In this same lot of potatoes the percentage of hollow heart in any size class increased rapidly as the size of tubers increased. Hollow heart occurred in 52 per cent of the tubers weighing 376 to 525 grams (13 to 18 ounces); in 78

[1] Paper No. 2552 of the Scientific Journal Series of the Minnesota Agricultural Experimental Station.

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[3] Senior Physiologist, Division of Fruit and Vegetable Crops and Diseases, The Red River Valley Potato Research Center, East Grand Forks, Minnesota. (Report of a study in which certain phases were carried on under the Research and Marketing Act of 1946.)

per cent of the tubers weighing 526-675 grams (18-24 ounces); and in 100 per cent of the tubers weighing more than 675 grams. Moore (7) found that 20-pound lots having a low tuber count had more hollow heart than 20-pound lots containing a larger number of tubers. However, hollow heart is not confined to large tubers. Werner (8) found that a small percentage of tubers weighing less than 75 grams (up to 2.75 ounces) were hollow. Even though Moore (7) found no hollow heart in tubers smaller than 2 ounces, Levitt (5) found incipient hollow heart in tubers as small as 1.8 grams and visible hollow heart in tubers as small as 15.3 grams (approximately ½ ounce).

Although it is well known that potato tubers having hollow heart are lower in specific gravity than are sound tubers, a search of the literature failed to disclose any reports on the possibility of using differences in specific gravity as a means of removing hollow heart tubers.

Harvey (2), in 1938, stated that X-rays could be used to detect hollow heart in potatoes but gave no data to indicate what percentage of the total hollow heart present such a method would detect.

## Materials and Methods

The study on the detection and separation of hollow heart tubers by size grading and by specific gravity determination was carried on in the fall of 1948. Approximately 200 pounds of ungraded Irish Cobbler potatoes were obtained from each of six growers in the Red River Valley area of Minnesota and North Dakota.

Each lot of tubers was divided into 6 size groups as follows: smaller than 1.5 inches in diameter; 1.5 to 2.0 inches; 2.0 to 2.5; 2.5 to 3.0; 3.0 to 3.5; and larger than 3.5 inches.

The tubers in each size were washed and then run individually through a series of salt solutions of the following specific gravities: 1.06, 1.07, 1.08, 1.09, and 1.10. Tubers that remained submerged in a salt solution but did not sink to the bottom were classed as having the same specific gravity as the solution. Although none of the tubers floated in water, some of the tubers floated on the surface of the solution having a specific gravity of 1.06 and this class is listed in the tables as "1.06 and below." Likewise, a considerable number of tubers sank to the bottom in the solution of specific gravity 1.10. Tubers of this class are listed in the tables as having a specific gravity of "above 1.10." Thus, all the tubers were graded into six specific gravity classes: 1.06 and below, 1.07, 1.08, 1.09, 1.10, and above 1.10.

After its specific gravity had been determined each tuber was weighed and cut open to determine the presence of hollow heart. Although a number of tubers had a small black necrotic area in the pith, which, according to Levitt

(5) is an incipient hollow, only those tubers that had definite hollows were counted as having hollow heart.

In a study carried out in the fall of 1944, 1,441 tubers (223 pounds) of Irish Cobbler, 1,279 tubers (234 pounds) of Early Ohio, and 1,625 tubers (238 pounds) of the Minnesota selection No. 6.39-4-40 grown at University Farm were examined for the presence of hollow heart first by X-raying and then cutting each tuber open. The X-ray apparatus was set up so that the tubers were placed on an endless belt which passed between the fluoroscope screen and the eyes of the viewer. Because the X-ray machines* tended to overheat when used almost continuously, it was necessary to turn off the machine about 15 minutes in every hour. With one man placing the tubers on the endless belt and another man examining the tubers as they passed over the fluoroscope screen, the 4,345 tubers were examined in about six hours, including the time required to allow the X-ray machine to cool.

Since the official United States standards for potatoes calculate tolerances for defects on the basis of per cent by weight, the hollow heart data in this paper are reported on this basis.

## Experimental Results

Table 1 gives the number and weight of potatoes, and weight and per cent of hollow heart potatoes in the six lots from the Red River Valley area. The incidence of hollow heart in these samples varied from 9.0 per cent in the sample from grower E to 60.4 per cent in the sample from grower D. The 182-pound sample from grower D contained only 289 tubers, which indicated a larger number of oversized tubers than were present in the lots obtained from the other growers.

Table 1—*Incidence of hollow heart in ungraded Irish Cobbler potatoes grown at six locations in the Red River Valley in 1948.*

| Number and Weight of Potatoes, and Per cent of Hollow Heart Potatoes in Lots Obtained from Indicated Locations: | | | | |
|---|---|---|---|---|
| Grower | Location | Number Tubers | Total Weight | Per cent Hollow Heart |
| | | Number | Pounds | Per cent* |
| A | Gilby, N. D. | 580 | 183 | 16.9 |
| B | Hatton, N. D. | 643 | 191 | 19.4 |
| C | Bygland, Minn. | 632 | 210 | 19.0 |
| D | E. Grand Forks, Minn. | 289 | 182 | 60.4 |
| E | McCanna, N. D. | 674 | 189 | 9.0 |
| F | Bygland, Minn. | 625 | 191 | 23.0 |
| Total | | 3443 | 1146 | 24.3 |

* By weight.

* Waite Portable 10 M.A.-80 Kv.P.; Shockproof Unit (Waite and Bartlett X-Ray Manufacturing Company, Inc.)

The distribution of the combined growers' samples in the six tuber size classes and the incidence of hollow heart in each size class are shown in table 2. The percentage of hollow heart tubers increased from 0 per cent of the tubers smaller than 1.5 inches in diameter to 78.0 per cent of the tubers larger than 3.5 inches in diameter. However, it is apparent from the distribution of the total hollow heart in the six size classes that the use of size grading to remove hollow heart from potatoes is not economically feasible since, in order to be sure of reducing the amount of hollow heart to a level below the 5 per cent maximum tolerance allowable for U. S. No. 1 potatoes, it would have been necessary to grade out all the tubers 2.5 inches in diameter and larger or about 62.5 per cent of the entire sample.

TABLE 2—*Distribution of Irish Cobbler potatoes grown in the Red River Valley in six size classes and the incidence of hollow heart in each class.*

| Tuber Size Class: | Total Weight, Weight Hollow Heart and Per cent Hollow Heart in Indicated Size Classes: | | | Distribution of Total Hollow Heart in the Six Size Classes: |
|---|---|---|---|---|
| Tuber Diameter | Total Weight | Weight Hollow Heart | Per cent Hollow Heart | |
| Inches | Pounds | Pounds | Per cent* | Per cent* |
| Smaller than 1.5 | 2 | 0 | 0 | 0 |
| 1.5-2.0 | 88 | 1 | 1.1 | 0.1 |
| 2.0-2.5 | 340 | 20 | 5.9 | 1.7 |
| 2.5-3.0 | 468 | 117 | 25.0 | 10.2 |
| 3.0-3.5 | 198 | 102 | 51.5 | 8.9 |
| Larger than 3.5 | 50 | 39 | 78.0 | 3.4 |
| Total | 1146 | 279 | 24.3 | 24.3 |

* By weight.

In considering next the relation of specific gravity of potato tubers to the incidence of hollow heart, the distribution of the 1,146 pounds of potatoes studied in six specific gravity classes and the weight and percentage of hollow heart in each class are given in table 3. These data show that hollow heart potatoes tend to be lower in specific gravity than sound potatoes. Of the potatoes having a specific gravity of 1.06 and below, 86.1 per cent had hollow heart, whereas only 5.3 per cent of the potatoes having a specific gravity of 1.10 had hollow heart. However, when the distribution of the total weight in the six specific gravity classes is considered, together with the hollow heart incidence in each class, it is seen that approximately 50 per cent of the hollow heart potatoes had a specific gravity of 1.08 to 1.09. In order to reduce the hollow heart incidence to a level below the 5 per cent maximum allowable

for U. S. No. 1 potatoes, it would have been necessary to remove all the potatoes having a specific gravity lower than 1.10, or approximately 52 per cent of the crop.

TABLE 3—*Distribution of Irish Cobbler potatoes grown in the Red River Valley in six specific gravity classes and the incidence of hollow heart in each class.*

| Specific Gravity Class | Total Weight, Weight Hollow Heart, and Per cent Hollow Heart in Indicated Specific Gravity Classes | | | Distribution of Total Hollow Heart in the Six Specific Gravity Classes: |
|---|---|---|---|---|
| | Total Weight | Weight Hollow Heart | Per cent Hollow Heart | |
| | Pounds | Pounds | Per cent* | Per cent* |
| 1.05 and below | 36 | 31 | 86.1 | 2.7 |
| 1.07 | 66 | 49 | 74.2 | 4.3 |
| 1.08 | 187 | 77 | 41.2 | 6.7 |
| 1.09 | 308 | 63 | 20.4 | 5.5 |
| 1.10 | 378 | 50 | 13.2 | 4.3 |
| Above 1.10 | 171 | 9 | 5.3 | 0.8 |
| Total | 1146 | 279 | 24.3 | 24.3 |

* By weight.

The distribution of the potatoes in the six size and six specific gravity classes, the incidence of hollow heart in these classes, and the distribution of the total hollow heart in these classes are shown in tables 4, 5, and 6, respectively. It is apparent that the incidence of hollow heart is greatest in the

TABLE 4—*Distribution of ungraded Irish Cobbler potatoes grown in the Red River Valley in six size classes and six specific gravity classes.*

| Tuber Size Class: | Pounds of Potatoes in Indicated Size and Specific Gravity Classes | | | | | | |
|---|---|---|---|---|---|---|---|
| Tuber Diameter | 1.06 and below | 1.07 | 1.08 | 1.09 | 1.10 | Above 1.10 | Total |
| Inches | Pounds | Pounds | Pounds | Pounds | Pounds | Pounds | Pounds |
| Smaller than 1.5 | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| 1.5-2.0 | 1 | 4 | 16 | 23 | 29 | 15 | 88 |
| 2.0-2.5 | 1 | 10 | 43 | 94 | 114 | 78 | 340 |
| 2.5-3.0 | 5 | 12 | 69 | 144 | 165 | 73 | 468 |
| 3.0-3.5 | 10 | 30 | 50 | 40 | 64 | 4 | 198 |
| Larger than 3.5 | 19 | 10 | 9 | 6 | 5 | 1 | 50 |
| Total | 36 | 66 | 187 | 308 | 378 | 171 | 1146 |

tubers of low specific gravity and larger sizes (Table 5). It is equally apparent from table 6 that hollow heart is so widely distributed throughout the size and specific gravity classes that neither size grading nor specific gravity grading nor a combination of the two offers a practical means of removing hollow heart. It would be possible to remove slightly over one-half the hollow heart by eliminating all tubers 2.5 inches and larger that had a specific gravity of 1.08 or less, or nearly one-fifth of the crop. To reduce the hollow heart of the entire sample to approximately U. S. No. 1 grade, it would have been necessary to eliminate all potatoes 2.0 inches and larger having a specific gravity of 1.09 or less, or nearly one-half the crop.

TABLE 5—*Incidence of hollow heart in potatoes in six size classes and six specific gravity classes.*

| Tuber Size Class | Per cent Hollow Heart in Indicated Specific Gravity Classes: | | | | | |
|---|---|---|---|---|---|---|
| Tuber Diameter | 1.06 and below | 1.07 | 1.08 | 1.09 | 1.10 | Above 1.10 |
| Inches | Per cent* | Per cent* | Per cent* | Per cent* | Per cent* | Per cent* |
| Smaller than 1.5 | .... | .... | .... | 0 | 0 | .... |
| 1.5-2.0 | 0 | 3.2 | 2.2 | 1.4 | 0 | 0 |
| 2.0-2.5 | 0 | 11.0 | 5.0 | 7.6 | 5.6 | 4.3 |
| 2.5-3.0 | 86.2 | 73.0 | 42.0 | 24.3 | 20.7 | 7.3 |
| 3.0-3.5 | 100.0 | 96.9 | 73.3 | 47.5 | 11.6 | 0 |
| Larger than 3.5 | 90.2 | 100.0 | 100.0 | 21.6 | 36.5 | 0 |

* By weight.

TABLE 6—*Distribution of total hollow heart in six size classes and six specific gravity classes.*

| Tuber Size Class | Distribution of Total Hollow Heart Percentage in Indicated Specific Gravity Classes | | | | | | |
|---|---|---|---|---|---|---|---|
| Tuber Diameter | 1.06 and Below | 1.07 | 1.08 | 1.09 | 1.10 | Above 1.10 | Total |
| Inches | Per cent* | Per cent* | Per cent* | Per cent* | Per cent* | Per cent* | Per cent* |
| Smaller than 1.5 | .... | .... | .... | 0 | 0 | .... | 0 |
| 1.5-2.0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.1 |
| 2.0-2.5 | 0 | 0.1 | 0.2 | 0.6 | 0.5 | 0.3 | 1.7 |
| 2.5-3.0 | 0.4 | 0.8 | 2.5 | 3.0 | 3.0 | 0.5 | 10.2 |
| 3.0-3.5 | 0.9 | 2.5 | 3.2 | 1.7 | 0.6 | 0 | 8.9 |
| Larger than 3.5 | 1.4 | 0.9 | 0.8 | 0.1 | 0.2 | 0 | 3.4 |
| Total | 2.7 | 4.3 | 6.7 | 5.5 | 4.3 | 0.8 | 24.3 |

* By weight.

Table 7 shows the incidence of hollow heart in three varieties of potatoes grown in 1944 as determined by X-raying and by cutting the tubers. With all three varieties, all the tubers separated out by the use of the X-ray apparatus were found to have hollow heart when cut open, but additional hollow heart tubers were found when the remaining tubers were examined by cutting. Approximately 75 per cent of the hollow heart in the Cobblers, 83 per cent of the hollow heart in selection No. 6.39-4-40, and 84 per cent of the hollow heart in Early Ohio were detected by X-ray examination. In the latter two varieties, which are shallow-eyed, the hollow heart tubers not detected had only small hollows. In the Irish Cobbler, in many instances X-ray shadows which could possibly have been due to the presence of hollow heart were attributed to the coincidence of two deep eyes on opposite sides of the tuber in the line of vision between the viewer and the fluoroscope screen, and such tubers were thus allowed to pass through as sound tubers. However, despite the failure to detect all hollow heart tubers, enough of the hollow heart was detected to reduce the incidence of hollow heart in the Irish Cobblers from 22.3 per cent to 5.7 per cent; in the selection No. 6.39-4-40 from 6.0 to 1.0; and in Early Ohio from 11.0 per cent to 1.7 per cent .

TABLE 7—*Incidence of hollow heart in three varieties of potatoes as detected by X-ray examination and by cutting, 1944.*

| Variety | Size of Sample Examined | | Weight of Tubers Found to Be Hollow When Examined by | | Incidence of Hollow Heart as Determined by | | Per cent of Total Hollow Heart Detected by X-ray |
|---|---|---|---|---|---|---|---|
| | No. of Tubers | Weight Tubers | X-ray | Cutting* | X-ray | Cutting* | |
| | Number | Pounds | Pounds | Pounds | Per cent | Per cent | Per cent |
| Cobbler | 1441 | 223.1 | 37.1 | 49.7 | 16.6 | 22.3 | 74.6 |
| No. 6.29-4-40 | 1625 | 238.5 | 11.8 | 14.2 | 5.0 | 6.0 | 83.1 |
| Early Ohio | 1279 | 233.9 | 21.7 | 25.8 | 9.3 | 11.0 | 84.1 |
| Totals | 4345 | 695.5 | 70.6 | 89.7 | 10.2 | 12.9 | 78.7 |

* Includes hollow heart tubers detected by X-ray.

## DISCUSSION

In years when hollow heart is a serious problem, as in 1948, this defect is found occasionally in small tubers and is common in tubers of best marketable size (2.0 to 3.5 inches diameter). In the six lots of tubers tested in 1948, which contained a total of 24.3 per cent hollow heart by weight, only 3.5 per cent occurred in tubers smaller than 2.0 inches and larger than 3.5 inches in diameter, whereas the remaining 20.8 per cent occurred in the size range varying from 2.0 to 3.5 inches. However, approximately 88 per cent of the

entire weight tested consisted of potatoes in this size range. On this basis it would be impossible to remove hollow heart from a crop of potatoes without, at the same time, throwing away most of the crop.

Although hollow heart tubers tend to have a lower specific gravity than sound tubers, a sufficiently high percentage of hollow heart tubers have as high specific gravity as sound potatoes to make it impossible to reduce the hollow heart incidence in a crop by specific gravity separation without, at the same time, excessively reducing the amount of salable potatoes. In addition, since the general range of specific gravities in crops of potatoes varies from location to location and from year to year, it would be necessary to determine the specific gravity to use as a point of separation between sound and hollow heart potatoes for each location and each year.

Even though the X-ray method appears to be the most promising as a means of detecting potatoes with hollow heart, this method would have to be tested on a pilot plant basis to determine if the cost in time and equipment is low enough to make such a method economically practical.

## Summary

1. A total of 1,146 pounds (3,443 tubers) of Irish Cobbler potatoes grown in the Red River Valley were graded into six size classes and into six specific gravity classes and the incidence of hollow heart in each size and specific gravity class was determined.

2. The percentage by weight of hollow heart in each size class ranged from zero in the tubers smaller than 1.5 inches in diameter to 78.0 for tubers larger than 3.5 inches in diameter. However, of the 24.3 per cent hollow heart present in the entire 1,146 pounds examined, 20.8 per cent occurred in the size range 2.0 to 3.5 inches, whereas the remaining 3.5 per cent occurred in the potatoes larger and smaller in size.

3. The hollow heart in each specific gravity class ranged from 86.1 per cent in the potatoes having a specific gravity of 1.06 and below to 5.3 per cent in the potatoes having a specific gravity above 1.10. However, in order to reduce the hollow heart incidence to a level below the maximum tolerance allowable (5 per cent) for U. S. No. 1 potatoes, it would be necessary to grade out all tubers having a specific gravity lower than 1.10, or approximately 52 per cent of the crop.

4. The X-ray examination of 1,441 tubers of Irish Cobbler, 1,625 tubers of selection No. 6.39-4-40, and 1,270 tubers of Early Ohio potatoes in 1944 resulted in the detection of 74.6 per cent, 83.1 per cent, and 84.1 per cent, respectively, of the hollow heart present in these varieties. The total hollow heart present in the 695 pounds of tubers examined was reduced from 12.9 per cent to 2.7 per cent through the use of this method of detection.

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## I. THE BREEDING OF RESISTANT VARIETIES OF POTATOES

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### 1. The Basis for the Breeding of Potatoes Resistant to Late Blight (*Phytophthora infestans*, de Bary)

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Phytophthora-epidemics in the middle of the 19th century incited the start of the breeding work with potatoes without the knowledge of the causal relations between the parasite and the host. Goodrich (1948) crossed Phytophthora resistant wild species with cultivated susceptible forms and in this manner established the basis of breeding for resistance in this sphere. In a similar way worked Klotzsch (1852), who crossed *Solanum demissum utile* with cultivated varieties and Baker (1883), Pringle (Hollrung 1932) and Sutton (1896). Sutton used *S. maglia* and *S. commersonii.*

In the following years first important hints to differences in the susceptibility of cultivated varieties and for the existence of genes for resistance within the wild species *S. polyadenium*, *S. commersonii*, *S. stoloniferum*, *S. bulbocastanum* and *S. verrucosum* have been given by examination by Hekkel (1898), Woods (1903), Labergerie (1904), Jones (1905) and especially of Stuart (1905). Furthermore Broili (1921) tested *S. edinense.* Their results

Contribution from the Max-Planck-Institute for Researches in Plant Breeding, Voldagsen über Elze (Hanover).

were of no practical importance. The same is to be said about the researches of Paterson (1853), Sutton (1896), Torbitt, Woods (1903), Jones (1905), *etc.*, who tried to get highly resistant forms by rearing of seedlings, selection of clones and crosses within *S. tuberosum*.

A new chapter began, when Müller (1925) used systematically certain wild hybrids for his crosses and Reddick (1928) and Salaman (1932) supplied new informations about wild cultivated forms. When physiological specialization of the fungus was known, the extensive crossings of *demissum* x *tuberosum* of the Kaiser-Wilhelm-Institute for Plant Breeding Researches (Müncheberg-Mark) (Baur and Schick, 1932 *et seq.*) became important. Besides that a systematic analysis was made of the resistance of all the wild and cultivated forms which were available (from expeditions by Bukasov (1925), Juzepczuk (1929), Vavilov-Kesselbrenner (1932), and Baur-Schick (1930-1931). The most significant result of the following decade was the delivery to private breeders of some very promising highly resistant hybrid clones. But when the number of biotypes of Phytophthora rose from 2 (Schick, 1932) to 8 (Lehmann, 1936) new problems opened. These problems directed the research work of the following years.

After the transfer of the Institute from Müncheberg-Mark to Voldagsen (Hanover), work was continued with the same purpose. On the following pages, results, especially from 1936-1949, shall be referred to.

*Methods*

Schick (1932) proved the existence of specialized races of *P. infestans* by comparing Müller's W-races, *demissum* x *tuberosum* hybrids from Müncheberg and cultivated strains. Previously Müller had found morphological and physiological differentiation within 12 examined origins of Phytophthora. He thought this differentiation was due to mutations of a hypothetical original form.

The discussion about the appearance of biotypes has never stopped since. The appearance of new biotypes may have different causes: first, it may be the result of sexual events which lead to new combinations, but nearly nothing is known about this possibility; second, mutations may occur. In special cases resistant plants may act as "inductors" (Müller, 1937), and third, there may be a selective effect by partly resistant plants on populations. Yet this has not been observed within commercial varieties with normal susceptibility. Finally it has been established (Reddick and Mills, 1939), that the fungus is extraordinarily plastic (potential). Consequently its virulence may be influenced by passages through host plants of different grades of resistance. Therefore hybrids with different grades of intermediate resistance may induce the fungus to augment its virulence so that one day it even may affect the completely resistant hybrids (Reddick, 1943, Reddick and Peterson, 1945). It remains to be seen whether this process occurs frequently and whether it takes the same

course in all resistant species and hybrids. To answer this question we are using the partially resistant hybrid variety Aquila as the host plant. At the moment the 10th passage on Aquila is proceeding. It remains to be proved, if the original race will have changed its parasitic behavior.

In 1936 our Institute had already four biotypes, differentiated on a collection of 25 hybrid clones (out of *S. demissum utile* x *S. tuberosum*) of $F_1$ to $F_4$ generations. (Schick and Lehmann, 1936). Besides Schick and Schaper (1936) could prove by infection experiments that a number of different forms of *S. demissum* behaved differently when infected with these biotypes. This result could be explained genetically. At the same time it confirmed the possibility of distinguishing different biotypes of late blight on differential clones. A short time after biotype 5 on *S. antipoviczii* (Koreniewo-Russia) had been found by means of 50 differential clones. In the same year the biotypes 6, 7 and 8 could be isolated from infected seedlings in the hot-bed, which were resistant to biotypes 1-4 (Lehmann, 1938). Biotype 8 was found to be the most virulent race. These 8 biotypes formed the basis for all further investigations in the Institute until 1944.

Besides the problem of specialization, the questions of sexuality, modificability by exterior influences, sporangia and zoospores were studied. The investigations on the biology and cultivation of the fungus by Müller (1925), Vowinckel (1925), Zimmermann (1927), Reddick, Crosier and Mills (1932) and Salaman (1931) had given the basis for this research work in our Institute. The steadily improved methods permitted for easy isolation of biotypes, sure separation through cultures on artificial substrate and rapid passages from agar substrate *via* tubers to foliage. In this way sufficient clean infection material could be provided for the testing of large numbers of seedlings. A new method for the infection of young seedlings and of cuttings was developed by Stelzner and Lehmann (1939), which allowed for the testing of much plant material in relatively little space.

By the end of the war all biotypes were lost as well as the differential clones and part of the breeding material. Not until 1947 could we start again the mycological researches, though all experimentation was hampered by the lack of laboratory implements.

During the summer of 1947, on account of dry hot weather, the conditions for infection with late blight in the potato field were very unfavorable. However, in the late autumn we succeeded in isolating a population from a hybrid of *S. polydenium* x *S. chacoense* and in producing single-spore-lines from it. Several varieties, wild species, and hybrid clones have been tested with this material, with the result that this first biotype 48/1 corresponded in its parasitic behavior to one of the weaker biotypes of Müncheberg. This biotype was

lost again in the autumn of the following year by bacterial infection. Some other populations of late blight were isolated in 1948 from infected hybrid clones of *S. demissum* x *S. tuberosum*. Comparative investigations demonstrated that 4 of these populations were differentiated by their most virulent races. The analysis by single-spore-lines of these 4 populations is planned for this year. So we hope to have again 4 biotypes of late blight at our disposal, the identity of which with the old biotypes 1-8 of Lehmann cannot be proved. Furthermore, we are occupied by building up again a collection of test clones for the differentiation of the most virulent races of late blight with the aid of wild species and hybrids.

To select suitable resistant forms of wild species and hybrids with the object of breeding completely resistant strains of commercial value, we use the following methods: (1) Observation of the attack of late blight in the open field; (2) artificial infection of young seedlings; (3) control with cuttings from them; and (4) a supplementary test of the tubers. The latter does not correspond to all claims, since without petri dishes we must use bags of synthetic materials as containers for the infected tubers. Therefore the grading, with regard to development of mycelium, cannot always be done with quite reliable results. Our view, however, is that these tests will suffice for practical purposes.

The necessity of selecting strains of potatoes resistant to virus diseases and to the Colorado beetle has induced us to analyze all available wild species with regard to resistance to the diseases mentioned.

The results of one year's experimentation have lead to a classification of the commercial varieties now grown in Germany (Section 2) with regard to their behavior against *P. infestans* and their suitability as parents for crossings. Furthermore, they have, with restriction to one biotype, confirmed resistance or susceptibility of several wild species of different origins (Section 3.) They at last have led to the elimination of some susceptible hybrid clones, which facilitates further work with this material.

## 2. Susceptibility and Resistance of Cultivated Potatoes

The endeavorings of the private plant breeders for selection and propagation of late blight resistant varieties and the delivery to them of pre-selected wild species and hybrid clones from Research Institutes, caused considerable changes in the collection of registered varieties since 1936. More and more varieties, which contain genes for resistance to late blight from wild species, have replaced older susceptible varieties. The varieties "Empire," "Placid," "Chenango," "Smith's Orion," "Craig's Snow White," *etc.*, constitute examples of such foreign selections which are derived from *S. demissum*, *S. maglia*, *S. jendleri* and others. In the same way several German varieties were originated

and have been taken into the assortment of registered varieties. Therefore, according to the results of our experiments we form two groups:

a) The *tuberosum* varieties (*tuberosum* x *andigenum*)

b) The hybrid varieties.

*The tuberosum varieties*

This group contains all the cultivated varieties which definitely or with high probability originate in *S. tuberosum* and *S. andigenum*. From the point of view of their phylogeny these two belong very closely together. Today they still cover the greater part of the German assortment of commercial varieties. This susceptible group may be contrasted with the second group which contains genes for resistance from wild species.

*The hybrid varieties*

The specific behavior of the hybrid varieties depends on the participation of a wild species, in Germany, particularly that of *S. demissum*. Clones possessing the genes from both *S. tuberosum* and *S. demissum* must be counted as hybrid, upon which a specialization of distinct *Phytophthora* biotypes is possible and which therefore can be used as test-clones in an assortment.

The need of separation of the two groups of *tuberosum* varieties and hybrid varieties results from table 1 which contains some comparable experiments of the year 1948.

TABLE 1—*Results from artificial infection of tubers with late blight.*

| *Phyt.* infection | | | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|---|---|
| I. | | Mensa | 31.0 | 36.0 | 35.5 | 36.0 | 33.0 | 32.5 | 33.5 | 36.5 |
| | | Mittelfrühe | 36.5 | 39.0 | 37.5 | 35.5 | 36.0 | 35.0 | 36.5 | 37.5 |
| | | Gemma | 33.5 | 36.5 | 36.0 | 37.0 | 35.0 | 34.5 | 35.5 | 37.0 |
| | | Vera | 34.5 | 35.0 | 34.5 | 36.5 | 36.0 | 35.5 | 35.5 | 35.0 |
| | | Flava | 38.0 | 34.5 | 39.0 | 34.5 | 38.0 | 32.5 | 36.5 | 39.5 |
| II. | a. | Falke | 1.3 | 2.0 | 4.7 | 6.0 | 6.0 | 6.6 | 7.3 | 8.0 |
| | | Aquila | 1.5 | 19.0 | 9.5 | 7.0 | 17.5 | 15.0 | 10.0 | 17.5 |
| | | Panther | 2.0 | 6.5 | 18.9 | 2.0 | 8.5 | 9.0 | 16.0 | 9.5 |
| | b. | Frühnudel | 20.5 | 34.0 | 34.0 | 32.0 | 30.1 | 20.4 | 24.5 | 32.6 |
| | | Pommerbote | 24.0 | 30.0 | 35.5 | 16.5 | 34.5 | 25.0 | 30.0 | 30.5 |

Testing of varieties with different populations of *P. infestans*.
Figures signify the grades according to Lehmann of 8 halves of tubers per strain or variety.
Grading scales 0-5=missing to very strong browning for each half of tuber.
Group I=flowing washed type of infection.
Group II=necrotic, more or less sharply limited type of infection.

The results, of course, are not definite ones, but they allow for the differentiation of two groups of varieties:

1. The very susceptible Group I is attacked uniformly by all populations of late blight, so that a differentiation is not possible on these varieties.

2. Group IIa is distinguished by minor degrees of susceptibility. The populations A, B and C can be differentiated clearly. The infected tubers show single specks.

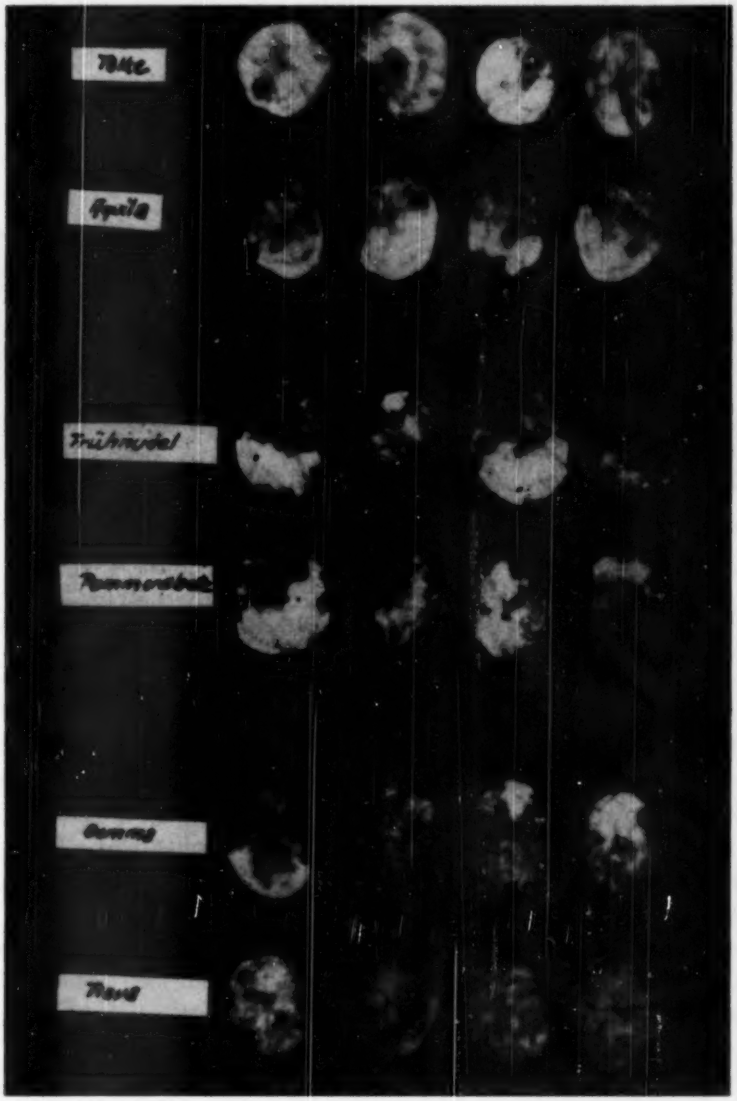

FIG. 1—Different populations of late blight on three hybrid varieties with the limited necrotic type of infection.

| Pertaining Figures of Grading: | I* | II | III | IV |
|---|---|---|---|---|
| Falke | 1.3 | 6.0 | 4.7 | 7.3 |
| Aquila | 1.5 | 3.5 | 9.5 | 10.0 |
| Panther | 2.0 | 5.0 | 18.9 | 16.0 |

I*=left half, scarcely infected, is shaded in the photo.

Group IIb is distinguished by greater susceptibility. Nevertheless there are differentiated types of infection. The infected tubers are damaged heavily, but there remains always a sharp limit between healthy and infected tissue.

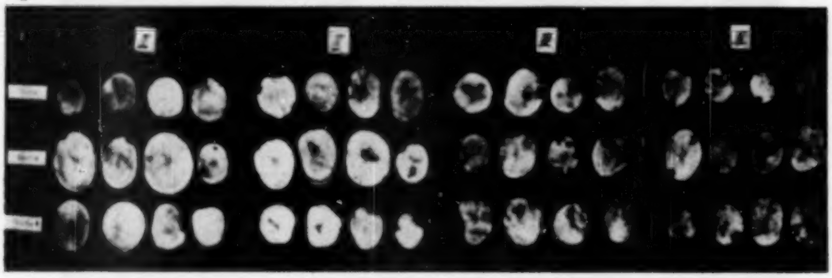

Fig. 2—Infceted tubers of Group I and II. Differences in the manner of browning.

Figures of Grading:

| Flava | Gemma | Pommernbote | Frühnudel | Aquila | Falke |
|---|---|---|---|---|---|
| 39.0 | 36.0 | 35.4 | 34.0 | 9.5 | 4.7 |

The lack of genes for resistance ["major genes" in the sense of Black (1943, 1945, 1947)] in Group I and their existence in Group II are clearly noticeable. The obtained results are not in contradiction with the effect of modifying minor genes, which have not yet been identified, on the differentiation of susceptibility in varieties of *S. tuberosum* (*S. andigenum*).

For a long time it is known that varieties of *S. tuberosum* show differences in their behavior to one biotype (Jones *et al.*, 1912), Müller (1925), Vowinckel (1925), Reddick (1928), Köck (1931), Salaman (1932), Sidorov (1937), Stevenson *et al.* (1937), Stelzner and Lehmann 1939), Bonde *et al.* (1940).

## Results of Foliage Infection

The classification of the varieties of Group I according to different grades of infection is difficult, as the latter are strongly modified by ecological conditions. Considering the time of incubation, formation of sporangia in the foli-

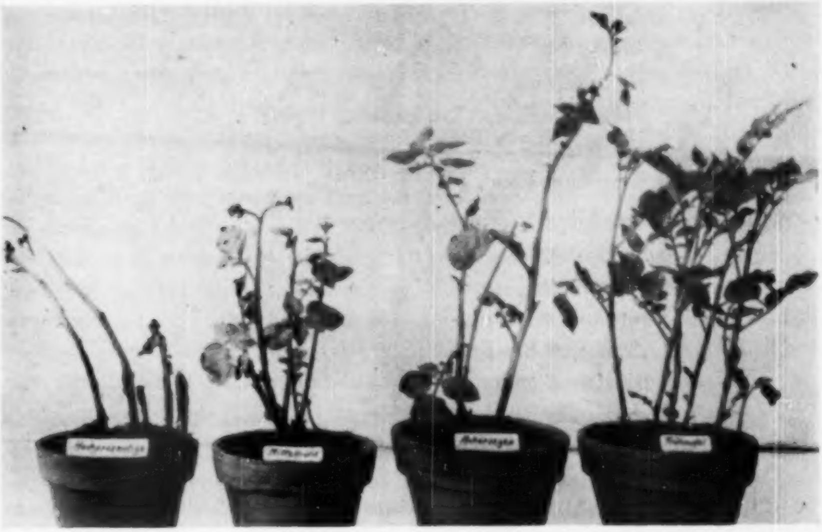

FIG. 3—Types of infection on foliage of three varieties of *S. tuberosum* (left) and one hybrid variety (right) (produced by biotype 48/1).

age and of mycelium on the tubers, as well as the type of infection in the nursery in 1948, when a very severe attack of late blight occurred, the following results with 74 varieties were obtained:

Susceptible in lesser degree:

Ackersegen, Fram, (Havilla*), Merkur, Spätrot, Urtica, Voran.

Medium to highly resistant:

Aquila, Carla, Erika, Falke, Frühnudel†, Panther, Pommernbote†, Roswitha.

Of course, these varieties of Groups I and II should be preferred for crossings.

### 3. Analysis of the Wild Species

A detailed description of the behavior of wild species tested in our Institute has been given by Lehmann (1937) and Stelzner and Lehmann (1939). The basis for the classification was formed by the results of the trials with 8 biotypes.

Completely susceptible to All Biotypes:

*S. verrucosum**

*S. chacoense* (Paraguay, Siambon, *v.* Bukas)

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*The descendance of Havilla is not known.

†Frühnudel and Pommernbote have shown heavy infection of the tubers, but good resistance in foliage.

* Selected lines of the species.

*S. jamesii*
*S. henryi*
*S. commersonii*
*S. acaule* (high and low growing types)
*S. fendleri*
*S. demissum* Redd. 526

Different Susceptibility to Single Biotypes:

*S. verrucosum**
*S. antipoviczii**
*S. ajuscoense**
*S. demissum* Rio Frio
*S. demissum utile*
*S. demissum* Redd. *v.* Pringle
*S. demissum v.* Bukasov
*S. demissum* Redd. 531
*S. demissum xitlense*
*S. demissum* Redd. 519

Completely Resistant to All Biotypes:

*S. polyadenium*
*S. verrucosum**
*S. antipoviczii**
*S. ajuscoense**
*S. demissum tlaxpehualcoense*
*S. demissum* Lindl. 029
*S. demissum* El Desierto Redd. 530

On *S. demissum tlaxpehualcoense, S. demissum* Lindl. 029, *S. polyadenium* once light infection without or with single spores was observed.

Additionally we can classify in the susceptible group on the basis of tests with biotype 48/1: *S. macolae* (number of testing seedlings: 250), *S. catarthrum* (260), *S. cordobense* (30), *S. leptostigma* (18), *S. wittmackii* (2). The forms of *S. demissum* Redd. 521, (200), Rio Frio (90), *xitlense* (300), Lindl. 029 (138), El Desierto Redd. 530 (300), *tlaxpehualcoense* (300), *S. ajuscoense* (2) and *S. polyadenium* (25) remained uniformly resistant to this biotype. The following classification of the wild species according to their resistance was prepared by Reddick (1934) and Bukasov (1936), who judged to be resistant: *S. demissum, S. semidemissum, S. coyoacanum, S. neoantipoviczii, S. verrucosum, S. polyadenium, S. sambucinum, S. bulbocastanum, S. ajuscoense.*

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* Selected lines of the species.

Lehmann undertook for the first time (1939, 1941) to clear up the *genetic basis* of *S. demissum* for resistance to Phytophthora by means of homozygous lines. From crossings of the types (+R, +R 5) (resistant to biotypes 8 and 5), (—R 8, —R 5) and (—R 8, +R 5) he could conclude that *S. demissum* transfers resistance in dominant manner with one gene. The mode of heredity is the same with different biotypes. Up to now the splitting up of resistance to single biotypes has not yet been observed in *S. demissum tlaxpehualcoense, S. demissum* Lindl. 029 and *S. demissum* El Desierto Reddick 530, therefore we believe that these species transfer their complete resistance against the 8 biotypes. *S. dem.* (+) x *S. dem* (—) = $F_1$ resistant, $F_2$: 3 resistant : 1 susceptible. *S. dem.* (+) x *S. acaule* (—) = $F_1$ resistant; *S. acaule* (—) x *S. dem.* (+) = $F_1$ resistant; *S. dem.* (+) x *S. tuberosum* (—) = $F_1$ resistant. These results are to be expected if *S. demissum* is homozygous for resistance.

*S. polyadenium* as a species can be looked at in the same way as the completely resistant forms of *S. demissum*. The species as a whole seems to be resistant. *S. polyadenium* x *S. jamesii* gave a susceptible $F_1$. All the $F_1$ descendants of *S. polyadenium* x *S. chacoense* were susceptible in 1948.

*S. verrucosum* consists of lines which can be classified from wholly susceptible to wholly resistant. Resistant seedling plants must be tested by selfing whether they split up in resistance and susceptibility. Within *ajuscoense* and *antipoviczii* the existence of resistant and susceptible lines to single biotypes has been proved. According to Lehmann, *S. verrucosum* (+) x *S. tuberosum* (—) is resistant in $F_1$; *S. ajuscoense* (+) x *S. fendleri* (—) susceptible in $F_1$; and *S. beyacense* (—) x *S. ajuscoense* (+) is resistant in $F_1$.

*S. polyadenium* offers new chances since Stelzner (1942) succeeded in hybridizing this species with *S. tuberosum*. We have selected late blight resistant $F_2$, hybrids in 1948. This species is equally important as a resistant parent in the selection for resistance to the Colorado beetle (s. Torka) and virus resistance (s. Baerecke and Ross in this contribution).

The grade of resistance of the selected lines of *S. verrucosum* is not as high as that of the completely resistant forms of *S. demissum*. Hybridization with *S. tuberosum* was not yet successful, but the hybrid *S. demissum* x *S. verrucosum* with 48 chromosomes has been obtained and is promising for hybridization with *S. tuberosum* (Stelzner and Lehmann, 1939).

The selected resistant lines of S. *ajuscoense* and *S. antipoviczii* offer considerable difficulties in hybridization with *S. tuberosum,* but we have succeeded in getting such hybrids which offer good chances for the selection of late blight resistant varieties.

The hybrids of the different forms of *S. demissum* x *S. tuberosum* are of special interest and will be considered in more detail.

### 4. The Testing of Hybrid Clones Selected for Resistance to Late Blight in 1947-1948

Most of these hybrids have resulted from hybridization with different forms of *S. demissum*. As a result of the infection of foliage and tubers with biotype 48/1 in 1947, of the 358 tested clones 330 were susceptible. Resistant in foliage were only 12 clones and highly resistant in foliage as well as in tubers were 16 clones. Twenty-eight clones were selected as resistant. In 1947 we were not able to test the resistance of these clones in the nursery as late blight did not occur at all. In 1948, however, there appeared a very heavy natural infection in the nursery. All 12 clones, resistant in foliage, were selected on the basis of artificial infection and remained without any attack, and the same was the case with the 16 clones which had been selected as resistant in foliage as well as in tubers.

The following table gives the descendance of the highly resistant clones:

| Clone Number | Descendance |
|---|---|
| 588 | Aquila x [(*S. tub.* x *S. andig.*) x Mittelfrühe] |
| 589 | Aquila x [(*S. tub.* x *S. andig*) x Mittelfrühe] |
| 592 | [(*S. dem.* x *S. chac.*) x *S. tub.*] x Rubingold |
| 593 | Flava x [(*S. dem.* res x *S. tub.*) $F^1_2$ x Mittelfrühe] |
| 609 | (*S. dem.* res. x *S. tub.*) $F^1_3$ |
| 611 | [(*S. dem. utile* x *S. tub.*) $F^1_3$ x Mittelfrühe] x Erika |
| 612 | (*S. dem.* res. x *S. tub.*) $F^1_2$ x Sickingen |
| 613 | (*S. dem.* res. x *S. tub.*) $F^1_2$ x Sickingen |
| 614 | [(*S. dem.* res. x *S. tub.*) $F^1_2$ x Sickingen] x Voran |
| 616 | (*S. dem. utile* x *S. tub.*) $F^1_3$ x Aquila |
| 618 | [(*S. dem.* res. x *S. tub.*) x (*S. dem.* res. x *S. tub.*)] x Hybrid *S. dem. utile.* |
| 619 | [(*S. dem.* res. x *S. tub.*) $F^1_2$ x Mittelfrühe] x (*S. tub.* x *S. andig.*) $F^1_2$ |
| 620 | Flava x [(*S. dem.* res. x *S. tub.*) $F^1_2$ x Mittelfrühe] |
| 627 | [(*S. dem.* res. x *S. tub.*) $F^1_2$ x Mittelfrühe] (*S. tub.* x *S. andig.*) $F^1_2$ |
| 633 | [(*S. dem.* res. x *S. tub.*) $F^1_2$ x Stärkereiche] x [*S. dem. utile* x *S. tub.*) $F^1_2$ x Mittelfrühe] |
| 634 | [(*S. dem. utile* x *S. tub.*) $F^1_3$] x [(*dem. utile* x *S. tub.*) $F^1_2$] |

In 1948 hybrid clones were infected with biotype 48/1. Of the 232 clones, 75 were susceptible in foliage and 157 resistant in foliage. Of these 157 resistant clones 38 were eliminated because they were not promising in other characters. Of the remaining 122 clones, 85 could be classified as free from attack under the severe natural infection in the nursery. The following table gives the descendance of the cited clones and their behavior after artificial infection in the nursery. The results of the testing of the tubers have not yet been obtained.

| | Descendance | Tested Clones | Resistance to 48/1 | Eliminated Clones | Resistance in the Open Field |
|---|---|---|---|---|---|
| 1. | From seeds of hybrid clones of *S. demissum*/free pollination | 18 | 11 | 1 | 3 |
| 2. | From seeds of hybrid clones of *S. demissum*/selfed | 81 | 73 | 16 | 40 |
| 3. | From crossings of partially resistant hybrid clones of *demissum* with one another | 25 | 20 | 7 | 10 |
| 4. | Hybrid clones of (*S. demissum* x *S. tub.*) x*S. demissum* | 15 | 11 | 2 | 7 |
| 5 | From selfed European varieties | 18 | 2 | 2 | .... |
| 6. | (*S. dem.* x *S. rybinii*) x Edelgard | 6 | 2 | 1 | .... |
| 7. | (*S. dem.* Rio Frio x *S. verruc.*) x Falke | 1 | 1 | .... | 1 |
| 8. | [(*S. dem.* Lindl. 029 x *S. verruc.*) *x* Fram] x Flava | 1 | 1 | .... | 1 |
| 9. | [(*S. dem.* Lindl. 029 x *S. verruc.*) x Goldwährung x Flava | 4 | 2 | .... | 2 |
| 10. | (*S. dem.* Klotzsch x *S. kesselbrenneri*) x Ackersegen | 2 | .... | .... | .... |
| 11. | [(*S. dem.* x *S. ryb.*) x Flava] x Flava | 10 | 4 | 1 | 3 |
| 12. | [(*S. dem.* x *S. ryb.*) x Flava] x Falke | 1 | 1 | .... | 1 |
| 13. | [(*S. dem.* x *S. ryb.*) x Flava] x Mittelfrühe | 1 | 1 | .... | 1 |
| 14. | [(*S. dem.* x *S. ryb.*) x Edelgard] x Mittelfrühe | 2 | 1 | .... | 1 |
| 15. | [(*S. dem.* x *S. ryb.*) x Erika] x Edelgard | 1 | 1 | .... | 1 |
| 16. | [(*S. antipoviczii* x *S. ryb.*) x Edelgard] x (*S. tub.* x *S. and.*) | 12 | 6 | 2 | 1 |
| 17. | (*S. dem. xitl.* x *S. verruc.*) x (*S. tub.* x *S. and.*) | 2 | 2 | .... | 2 |
| 18. | (*S. salamanii* Nr. 5010 x Flava) x Edelgard | 10 | 6 | 4 | 2 |
| 19. | [(*S. dem.* x *S. ryb.*) x *S. tub.*] x | | | | |
| | (*S. tub.* x *S. and.*) | 1 | 1 | .... | 1 |
| 20. | Edelgard x *S. antipoviczii* | 2 | .... | .... | .... |
| 21. | Voran x *S. antipoviczii* | 1 | 1 | .... | .... |
| 22. | (*S. tub.* x *S. polyad. colch.*) x Aquila | 18 | 10 | 2 | 8 |

Another series of hybrid clones was tested for resistance with 4 populations of late blight of different virulence. From 177 clones 121 proved to be highly susceptible. Twenty-one clones were completely resistant. During the post-war years of 1945 and 1946 the selection work was continued without the possi-

bility of testing the breeding material by artificial infection. As a result of this difficulty hybrid clones had been selected for resistance only on account of their behavior in the nursery. Therefore it is not astonishing that many hybrid clones had to be eliminated corresponding to the results of artificial infection.

## Summary

1. An introductory historical survey of the breeding for late blight resistance is given.

2. The results of the investigation on specialization problems and on methods of selection for resistance for the interval of 1936-1945 (Müncheberg/Mark) and 1947-1948 (Voldagsen/Hann.) are discussed.

3. The assortment of commercial varieties must be divided into two groups: (I) Pure tuberosum varieties, which are highly susceptible with the exception of very few varieties with some degree of resistance. (II) "Hybrid varieties" with different degrees of resistance, which may be used as differential varieties in specialization researches.

4. Some more wild species could be classified with regard to their behavior to late blight. Their genetics of resistance and their suitability for hybridization is discussed. A report is given concerning the results of the testing of selected hybrid clones for the interval 1947-1948.

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# REPORT OF SEED POTATO CERTIFICATION AND REGULATION IN THE U. S. A. AND CANADA

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In order to prepare a report on seed certification regulations, the agencies in various states were requested to submit their latest regulations, and to indicate whether any changes had been made in the last two years, or whether any were contemplated. The examination of regulations from various states indicated that a minimum of changes was being made. These are classified as follows:

*Changes in Disease Tolerances*

| | New Tolerance | | Original Tolerance | |
|---|---|---|---|---|
| California—Reduction in Leaf Roll | 1st Insp. | 2nd Insp. | 1st Insp. | 2nd Insp. |
| Tolerance in Russet Burbank and Burbank | Fdn. 0.5<br>Cert. 0.5 | 0.25<br>0.5 | 1.0<br>4.0 | 0.5<br>3.0 |
| Colorado—Reduction in Total Virus Permitted | Fdn. 1.5<br>Cert. 4.0 | 0.2<br>1.0 | 2.0<br>5.0 | 1.5<br>3.0 |
| Idaho—Leaf Roll Tolerance Reduced | Cert. 0.5 | 0.5 | 1.0 | 1.0 |
| Total Virus Allowed in Southern Test Plot for Foundation Seed | 3.0 | | 5.0 | |
| Montana—Specific Virus Reduced<br>Spindle Tuber Leaf Roll | 1.0<br>0.25 | | 2.0<br>2.0 | |
| Washington—Total Virus Reduced | Fdn. 0.5<br>Cert. 3.0 | 0.25<br>2.0 | 1.0<br>4.0 | 0.5<br>3.0 |

## CHANGE IN GRADES

California added a Blue Tag single drop (½" to 2") grade. Maine reduced the size of the regular grade from 3½" (12 oz.) to 3¼" (10 oz.) None may be over 12 ounces in size. Nebraska increased the tolerance of sunburn and wire worm in Blue Tag and Green Tag Grades. North Carolina reduces the maximum size of their Certified seed to 10 ounces. South Dakota increased hollow heart tolerance from 5 per cent to 15 per cent. Wyoming increased the tolerances in Blue Tag and Green Tag Grades for flea beetle, wireworm and sunburn.

## FEE SCHEDULE CHANGES

Michigan raised the minimum fee from $5.00 to $10.00 and the acreage fee from 75 cents to $1.00 per acre. Nebraska shifted the fee schedule, although the total fee remains approximately the same. Washington changed the fee schedule. It was previously $5.00 per acre for ten acres or less, with

$4.50 per acre above 10 acres. The new schedule is $10.00 for two acres or less, with $4.50 per acre above two acres.

### Changes in Isolation Requirements

South Dakota reduced the isolation required from 10 rods to 1 rod. Nebraska will reduce isolation requirements from 75 to 50 feet.

Miscellaneous changes in regulations not classified under the above headings include an increase in the size of southern test plat samples, in Nebraska and New York. Nebraska requires 500 tubers planted in units to be tested from a five-acre or smaller field under irrigation, or a 15-acre field on the dry land. Larger fields must be represented by additional 500 tuber samples. New York State requires samples of 310 tubers, and reduces the tolerance for disease in the southern test plat in lots intended for Foundation stock.

The writer's observation on certification regulations in the various states indicates the enviable situation occupied by Canada. In that country a uniform set of regulations are applicable from one end of the Dominion to the other, whereas in the United States, a great variation exists among the states. Similar regulations, however, would not mean a uniform product, unless application of tolerances was similar.

## AMERICAN POTATO YEARBOOK

The 1950 edition of the AMERICAN POTATO YEARBOOK is off the press. The new volume contains seventy-six pages of interesting and vital information to the potato grower, the potato dealer and shipper, the potato research specialist and all those with an interest in the potato industry. It is again edited by John C. Campbell, Rutgers University, College of Agriculture, and is endorsed by the Potato Association of America.

Of special significance are feature articles by Dr. R. C. Wright of the United States Department of Agriculture on "Quality in Potatoes," and Harvey F. Noss, Executive Secretary of the National Potato Chip Institute on "The Potato Chip Industry—An Increasing Outlet for Good Potatoes." There is also an up to date list of more than 100 references to potato culture in the United States. Other interesting items include rules and regulations affecting the shipment of seed potatoes, price support schedules, a map indicating leading potato growing areas in this country, a list of leading United States and Canadian associations engaged in improvement of the potato industry together with the names of United States and Canadian seed certification officials. THE YEARBOOK also gives information on how and where to secure helpful brochures and leaflets covering many phases of the potato industry.

The book contains much statistical information of value. There are tabulations by states of both seed and table stock production as well as statistics on Canadian and world potato production. Other important features include

a list of periodicals of interest to the potato industry, reviews of recent books on the potato, a chart giving the amount of seed required and a classified directory of business concerns serving growers and dealers.

Copies of the YEARBOOK may be secured from the American Potato Yearbook, Editorial Office, 319 Scotch Plains Ave., Westfield, N. J. An individual copy sells for $2.00.

## SECTIONAL NOTES

### Indiana

We anticipate that many of our potato troubles will be over this year. I believe very sincerely that our growers can handle the potato situation much better than when we had Government controls for after our allotment was made our potato growers settled down and are apparently going to do a good job of growing potatoes. We have had considerable rain in the muck areas, which delayed planting to a certain extent but the crop has now been planted.

We are having some leafhopper and flea beetle troubles because of the fact that we had a large carry-over of the adult insects last year and nearly every duck or goose that flew north dropped off some leafhoppers on the potato fields. Our growers are not at all discouraged as they are spraying and dusting at the present time.

We have received numerous complaints from the County Agents and others interested in the waxing of potatoes trying to make the potatoes look better than they really are. Personally, I believe this has curtailed the sale of the potatoes because of the lack of experimental evidence on the value of waxing fruits and vegetables.—W. B. Ward

### New Jersey

The potato crop is growing rapidly and the plants in many fields are in full bloom. Most stands are fair to good and present prospects indicate that we will have a normal yield.

Many growers have started irrigating their potatoes and timely rains have prevented any drought damage where farmers are not equipped to irrigate. Because of the serious drought of last year many more growers have purchased irrigation equipment and at least one fourth of our 40,000 acres can now be irrigated.

The newly appointed Potato Marketing Agreement Committee has organized and Mr. John Fenton, formerly Executive Secretary of the New Jersey State Potato Association's Industry Committee, has been secured as the manager. Grade regulations and other details will soon be announced.

A group of 30 young potato growers from Aroostook County, Maine, visited several Central New Jersey potato farms on the 20th of June and were particularly interested in the amount of irrigation equipment in use.

The Annual Summer Meeting of the New Jersey State Potato Association was held on the 27th of June at Windsor in conjunction with the Annual Potato Festival which continued throughout the week. Both events were well attended.

### New York

Our acreage is about normal, if any such figure is possible. The season is late but our hopes are high.

The Marketing Agreement hearing was held in Rochester May 15-16-17. At this meeting arguments for a workable agreement for an area with various sized operations, many markets and numerous roads were presented. We shall await the results with interest. A referendum will be held in late July and August.

The Summer Field Day of the Empire State Potato Club will be held at Maurice Phelps farm just north of Chafee in Erie County on the 3rd of August. Interest of machinery men and growers alike insure a successful event. More than 20,000 people attended last year and this year demonstrations will be planned for more.—H. J. Evans.

### Oregon

There will be very little change from the 1949 potato acreage in the Klamath Basin this year. The seed being used is the best quality that we have had for many years. Only two lots sent to Oceanside for winter growing failed to make foundation. This, combined with better than usual quality land, should produce a particularly good crop if weather conditions are normal.

The shipping season is over with a total of 9,649 cars being shipped as of the 21st of May.—C. A. Anderson.

### South Dakota

Potato planting in South Dakota was delayed by the cold wet spring and many growers didn't get started until the 22nd of May. At this writing, the first of June, there are still many potatoes to be planted.

The commercial acreage in South Dakota for 1950 is down to 11,400, but most of this will be in the northwestern part of the state where the soil and the climate are ideal for potato production. The total potato acreage in the state for 1950 is expected to be 17,000, compared with 18,000 in 1949; and 22,000 in 1948.

The 1949 season was poor for most growers. The yields were low and so were the prices. The market was good in the fall with many shipments bringing $2.50 per hundred or better. After the 1st of January, it was hard to move stock much above support prices. The premium on certified stock was low until late in the season.

Dr. L. T. Richardson, associate pathologist from South Dakota State College, will supervise the field inspection work this season. Dr. Richardson came to South Dakota in 1949 from the University of Ottawa, Canada, where he had been working on potato diseases.

Because of the late season, field inspection will not start until late in June. —John Noonan.

### Province of Ontario

Committee members of the Potato Section, Ontario Crop Improvement Association, recently spent a full day discussing various topics relative to the industry. Resolutions adopted at this year's annual meeting were reviewed. Progress was reported on practically all. Several growers expressed their opinion in favor of discarding one grade of certified seed, and raising the standard of certified grade to that now set for "Foundation A."

With regard to table stock, there was an expression of opinion that present requirements of number one grade were not sufficiently high, as there was a trend for quality in all products. A suggestion was made to establish a special high grade for ten-pound packages. It was pointed out that rigid grading usually keeps at least twenty per cent of potatoes off the market, to be used as advantage for livestock feed, whereas at the same time, consumers use twenty-five per cent more potatoes because the quality is more satisfactory.

The Seed Potato Act, 1950 as passed at the last session of the Ontario Legislature was read and received. A Committee was appointed to draft regulations under same.

It was decided to endorse a plan to require inspection of all potatoes moving from the Provinces.

Some attention was given to the matter of cooking quality considering factors of variety, storage, maturity and supplies of plant food. Other topics discussed were cost of production survey, championship contest and high yield clubs, scab research, duty and quota, storage and marketing, enforcement of bacterial ring rot regulations and annual meeting.

A motion was passed favoring a tour of the committee to points in Northern Ontario during the coming season. The Executive Committee appointed for 1950 were: Charles McGuire, Colborne, Roy Hickling, Barrie, Howard Harper, Goodwood with R. E. Goodin, Toronto, as Secretary.—R. E. Goodin.

### Province of Prince Edward Island

Our season is fairly well advanced here. Normally our farmers do not complete planting until late in June, but this year it looks as though the bulk will be planted by the 15th.

Indications are that there will be at least a reduction of 10 per cent in

acreage and the trend in variety seems to be an increase in Sebagoes at the expense possibly of Green Mountains.

Although we have had excellent conditions so far, we shall need moisture during the next few weeks.—E. D. Reid.

### Canada

The Canadian certified seed potato deal is just about completed although fairly sizeable lots were moved during the last week of May. Despite the fact that the 1949 crop was by far the largest on record, sales have been extremely good and most of the stock has moved from the growers' farms. Prices have been rather low but this does not seem to have discouraged the growers greatly, as the indications are that there will be very little or no reduction in the acreage entered for inspection in 1950. In New Brunswick it is possible that there will be an increase of approximately 10,000 acres due to the fact that a new regulation has been placed in one of the Provincial Acts requiring all potato growers in the Saint John Valley to plant certified seed of one of the three classes. According to the Canadian regulations, fields planted with seed of Foundation or Foundation A classes only are eligible for inspection; whereas fields planted with the Certified class may be used for table stock only. It is believed, however, that most growers will plant seed of one of the first two classes and apply for field inspection with a view to certification. It is also anticipated that there will be a slight increase in the province of Quebec. However, as this province does not produce sufficient seed for their own use, this does not mean a great deal.

During the past five years growers in British Columbia have sent seed to Oceanside, California, to be tested during the winter. This project is fostered by the Northern Potato Growers' Association of that province. Each year the Canadian seed has stood up very well in comparison with lots of certified seed from various states participating in this project. The 1949 (1950) tests were no exception and have resulted in many orders being placed for Canadian seed.—J. W. Scannell.

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